PATENT SPECIFICATION

DRAWINGS ATTACHED

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The inventor of this invention in the sense of being the actual deviser thereof within the meaning of Section 16 of the Patents Act 1949 is: — HENDRIK BUIS, a Dutch citizen of 83, Ginasservis, France.

COMPLETE SPECIFICATION

Ultrasonic Apparatus for Measuring the Position of a Liquid Level

We, COMMISSARIAT A L'ENERGIE ATOMIQUE, an organisation created in France by ordinance No. 45—2563 of 18th October 1945, of 29 rue de la Federation, Paris 15e, France, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement: —

The invention relates to a method and apparatus using an ultrasonic emitter to determine the position of the level of a liquid inside a vessel to which access is difficult. The liquid may be, for example, a high-temperature molten metal, a bad conductor of heat or electricity or a flammable liquid, so that conventional measuring systems containing electrical contacts, photoelectric detectors, contact probes, and the like, cannot be used.

The invention relates more particularly, but not exclusively, to the measurement of the level of liquid sodium or of the eutectic mixture of sodium-potassium in the vessel of a fast-neutron reactor, where such a liquid is often used as a coolant.

Detecting apparatus exists which determines, in a liquid medium, the distance between an object and an ultrasonic emitter by measuring the propagation time of a wave train which goes to this object, is reflected from it and returns to receiver means which may also be coupled with the emitter. Such measurement is much affected by temperature gradients and variations in the composition of the liquid medium. Also, when the liquid metal level in the vessel of a nuclear reactor is measured, the measurement must take into account certain factors depending mainly on the position of the ultrasonic emitter relative to the vessel: if the emitter is inside the vessel it is impossible to service it and the irradiation to which it is subjected will greatly shorten its life; if it is outside the vessel, e.g. against the end of the vessel, the characteristic acoustic impedance of the emitter-vessel unit is such that the ultrasonic waves cannot generally penetrate the liquid medium, so that its level cannot generally be measured precisely.

The object of the invention is to provide apparatus without the disadvantages mentioned above and which permits, by means of an emitter outside the vessel, transmission of an ultrasonic wave train through the vessel wall for measurement, according to a known principle, of the time passing between two passages of the wave train past a given point, before and after reflection on the liquid interface whose position defines the level in the vessel.

According to the invention there is provided ultrasonic apparatus for measuring the position of a liquid level inside a vessel comprising, a transmitter of ultrasonic waves of a given frequency and a receiver for these waves, a tubular waveguide facing the transmitter and filled with an auxiliary liquid having acoustic properties similar to those of the liquid whose level is to be measured, the waveguide being closed in a fluid-tight manner by at least one plate whose thickness is equal to an integral multiple of half the wavelength, and a cylindrical envelope asso-

ciated with the waveguide and perpendicular to the level of the liquid whose level is to be measured for limiting movement thereof.

The invention also includes a method for measuring the position of a liquid level inside a vessel comprising the steps of transmitting ultrasonic waves of a given frequency through a waveguide immersed in the liquid, the waveguide being closed in a fluid-tight manner by at least one plate whose thickness is equal to an integral multiple of half the wavelength, and containing an auxiliary liquid having acoustic properties similar to those possessed by the liquid whose level is to be measured, reflecting the said waves from outside the waveguide in the liquid in such a manner that the reflected waves traverse the said liquid outside the waveguide in a contained manner and so that they are reflected back from the surface of the liquid through the body thereof and are hence reflected back through the waveguide to a receiver, the level of the liquid being determined from the time taken for a wave-train to complete an outward journey and return journey from the transmitter and back to the receiver.

The transmitter can therefore easily be placed outside the vessel containing the liquid, whether the vessel is metal or not, and the waveguide passes through the vessel wall by means of an appropriate fluid-tight system to introduce the ultrasonic wave train into the liquid.

Preferably, the transmitter is in a fluid-tight casing connected to the end of the waveguide and situated outside the vessel. Also, if the liquid contained in the waveguide reacts with the atmosphere or with the materials constituting the transmitter, and if this transmitter must be cooled, the casing may be filled with a liquid which will not react with that inside the waveguide if a leak occurs. The waveguide is closed at each end by fluid-tight discs which are transparent as far as the wave train is concerned and whose thickness is equal to half the wavelength. The waveguide may be welded to the casing of the transmitter and may be straight or slightly curved according to the geometry of the vessel wall and the manner in which it is to pass through this wall.

In a preferred embodiment of the invention, the waveguide is a straight cylindrical tube which passes vertically into the vessel containing the liquid and is associated with a conical reflector facing the tube and sending the wave train back in the direction of the level being measured, in the space between the waveguide and the cylindrical envelope.

If desired, the apparatus may also be provided with means for continuous calibration of measuring, providing reflections at levels whose precise positions along the waveguide and relative to the transmitter are known. To this end, the interior of the cylindrical envelope supports reflectors mounted at known levels and each having a plane surface which reflects the ultrasonic waves and is perpendicular to the waveguide axis.

The invention will now be described by way of example with reference to the accompanying drawings, in which:—

Figure 1 is a diagrammatical vertical section through ultrasonic measuring apparatus embodying the invention;

Figure 2 is a section on a large scale along a line II—II in Figure 1; and

Figures 3, 4, 5 show three modifications relating to the position of the apparatus relative to the wall of a vessel in which a liquid level is to be measured.

As Figure 1 shows, the apparatus consists mainly of a vertical tube 1 of uniform circular cross-section. The tube is filled with a suitable quantity of an auxiliary liquid 2, and its two ends are closed by identical plates or discs 3, 4 providing a fluid-tight seal between the tube 1 and the medium outside.

The tube 1 is rigidly connected to a casing 5 containing an ultrasonic transmitter or emitter/receiver device 6. This device sends a longitudinal wave train of frequency f in the direction of the tube 1 which acts as a waveguide as will be seen below. In order to allow the wave train to enter or leave the tube 1 through the plates 3, 4, the thickness of these plates is equal to $\frac{n\lambda}{2}$ where $n=1, 2, 3$ etc., λ designating the wavelength, i.e. the quotient of the speed of sound in the plate material by the frequency. The transmitter 6 has a support collar 7 secured and centered inside the casing 5 by three screws 8, permitting adjustment of the position of the transmitter in connection with an axial spring 9 bearing on the casing end 10. If the liquid in the tube 1 would react with the atmosphere or the transmitter materials, and if the transmitter must be cooled, the casing 5 is filled with a different liquid which will not react with that in the tube 1 if leakage occurs. A duct 11 passes through the casing and is connected by a duct 12 to the tube 1. This duct 11, normally closed by a plug 13, allows the tube 1 to be filled with a liquid 2. The casing 5 has cooling fins 14 on its external surface and ends in a flange 15 by means of which the casing and the tube 1 axially connected to it can be fixed to another flange 16 welded to the wall of a vessel 50 containing liquid 51 whose level is to be measured.

In the subsequent description it will be assumed that the vessel 50 is that of a nuclear reactor containing liquid sodium 51 whose level may vary inside this vessel. The auxiliary liquid 2 filling the tube 1 is preferably the eutectic mixture of sodium-potas-

sium whose properties are acoustically similar to those of liquid sodium and which does not solidify at the ambient temperature. Also this eutectic mixture will not react with sodium if it leaks from the tube 1. The third liquid cooling the transmitter 6 in the casing 5 is kerosene.

A metal bellows 18 provides a fluid-tight connection between the flanges 15, 16 and takes up any differences in expansion between the vessel and the tube 1. The apparatus is attached to the vessel 50 by three screws 19 secured by nuts 20.

The tube 1 passes vertically into the vessel through an orifice 21 in the vessel, and its lower end is immersed in the liquid sodium. A reflector 22 near that end of the tube 1 closed by the disc 4 is adapted to reflect the ultrasonic waves from the transmitter 6 along the tube 1. The reflector has two conical portions 23, 24 which are symmetrical relative to the axis of the tube 1 and which each end in an orifice 23*a*, 24*a* permitting continuous flow of the sodium contained in the vessel over the associated conical portions 23, 24. The reflector 22 is fixed by screws such as 25 in a support 26 rigidly connected to the flange 15. The upper part of this support 26 has an orifice 27 for the passage of the tube 1 and has an extension in the form of a tubular envelope 28, which encloses the tube coaxially, leaving an annular space 29 between its own internal surface and the external surface of the tube. Because of holes 30 at given places in the wall of the envelope 28, the space 29 is filled with the sodium contained in the vessel 50 up to the level 17.

The envelope 28 also contains reflector members such as 31 (Figure 2) at reference levels whose exact distance from the transmitter 6 is known. These reflector members — 3 in number in Figure 2 — are semi-cylindrical lugs perpendicular to the common axis of the tube 1 and envelope 28 and having plane surfaces facing the reflector 22. The lugs 31, preferably attached by their cylindrical surfaces and distributed uniformly along a helix, must be narrow and long enough to leave minimal clearance between their ends and the surface of the waveguide.

The apparatus described operates as follows. To measure the position of the level 17 of the liquid sodium contained in the vessel 50, the apparatus shown in Figure 1 is placed in the vessel. The metal bellows 18 ensures fluid-tightness where the apparatus passes through the wall of the vessel. Current is supplied to the transmitter 6, and an ultrasonic wave train — e.g. from a piezo-electric quartz crystal — traverses the liquid medium 2 (the eutectic sodium-potassium mixture) in the tube 1, passing through the terminal discs 3, 4 without notable attenuation. It should be noted that the longitudinal wave train moving in the guide is not influenced by the state of the surface of the tube 1, which may therefore be as desired. The wave train leaving the guide is reflected from the conical portions 23, 24 of the reflector 22 into the space 29 between the tube 1 and the outer envelope 28 so that it passes through the sodium parallel to the axis of the tube towards the level 17. The envelope 28 limits the movements of the liquid sodium which might interfere with measuring. The wave train is then reflected from the level 17 back along the same path, returning to the transmitter 6 along the tube 1 which has therefore enabled the wave train to traverse the vessel wall without notable attenuation during the outward and return journeys. Appropriate measuring means (not shown) are then used to define — as a function of the time taken for a wave train to complete an outward and return journey — the position of the liquid level 17 in the vessel relative to a known reference level which may be determined by means of the lugs 31. The lugs permit calibration of the apparatus at any time, since they define the corrections required on account of variations in the speed of sound due to temperature gradients and to any changes in the composition of the liquid sodium.

Figures 3, 4, 5 show diagrammatically three ways in which the measuring apparatus described may be mounted — as regards the position of the tube 1 and of the casing 5 containing the transmitter 6 — relative to the vessel 50 in which the liquid level is to be measured.

In Figure 3 the tube 1 passes vertically through the bottom of the vessel, eliminating the necessity for a reflector to send the ultrasonic waves towards the level being measured. In Figure 4 the tube passes through the side of the vessel and then bends inside the vessel, ending in a portion perpendicular to the liquid level in the vessel. In Figure 5 the tube 1 is associated with a reflector 32 in the form of a prism reflecting the ultrasonic rays through 90° on their way towards the level being measured and on their way back towards the transmitter.

WHAT WE CLAIM IS:—

1. Ultrasonic apparatus for measuring the position of a liquid level inside a vessel comprising, a transmitter of ultasonic waves of a given frequency and a receiver for these waves, a tubular waveguide facing the transmitter and filled with an auxiliary liquid having acoustic properties similar to those of the liquid whose level is to be measured, the waveguide being closed in a fluid-tight manner by at least one plate whose thickness is equal to an integral multiple of half the wavelength, and a cylindrical envelope associated with the waveguide and perpendicular

to the level of the liquid whose level is to be measured for limiting movement thereof.

2. Ultrasonic apparatus as claimed in Claim 1, wherein the waveguide traverses the wall of the vessel in a fluid-tight manner.

3. Ultrasonic apparatus as claimed in Claim 1 or 2, wherein the transmitter is in a casing connected to one end of the waveguide and which casing is filled with a coolant liquid which does not react with the auxiliary liquid.

4. Ultrasonic apparatus as claimed in Claim 3, wherein the coolant liquid is kerosene.

5. Ultrasonic apparatus as claimed in any preceding claim, wherein the waveguide is closed at each end by a fluid-tight plate whose thickness is equal to an integral multiple of half the wavelength in the material of the plate.

6. Ultrasonic apparatus as claimed in any preceding claim, wherein the waveguide is a straight cylindrical tube.

7. Ultrasonic apparatus as claimed in any of Claims 1 to 5, wherein the waveguide is a cylindrical tube having at least one bent portion.

8. Ultrasonic apparatus as claimed in any preceding claim, wherein the waveguide is arranged vertically and enters the vessel at the upper part thereof and is associated with a reflector system facing the waveguide and sending the waves back towards the level of said liquid in the space between the guide and the cylindrical envelope, the envelope being arranged coaxially with the guide.

9. Ultrasonic apparatus as claimed in any preceding claim, including means affording continuous calibration, said means creating reflections for the waves at reference levels whose positions along the guide and relative to the transmitter are known.

10. Ultrasonic apparatus as claimed in any preceding claim, wherein the auxiliary liquid contained in the waveguide is the eutectic mixture of sodium-potassium.

11. A method for measuring the position of a liquid level inside a vessel comprising the steps of transmitting ultrasonic waves of a given frequency through a waveguide immersed in the liquid, the waveguide being closed in a fluid-tight manner by at least one plate whose thickness is equal to an integral multiple of half the wavelength, and containing an auxiliary liquid having acoustic properties similar to those possessed by the liquid whose level is to be measured, reflecting the said waves from outside the waveguide in the liquid in such a manner that the reflected waves traverse the said liquid outside the waveguide in a contained manner and so that they are reflected back from the surface of the liquid through the body thereof and are thence reflected back through the waveguide to a receiver, the level of the liquid being determined from the time taken for a wave-train to complete an outward and return journey from the transmitter and back to the receiver.

12. Ultrasonic apparatus for measuring the position of a liquid level inside a vessel, substantially as described and as shown in the accompanying drawings.

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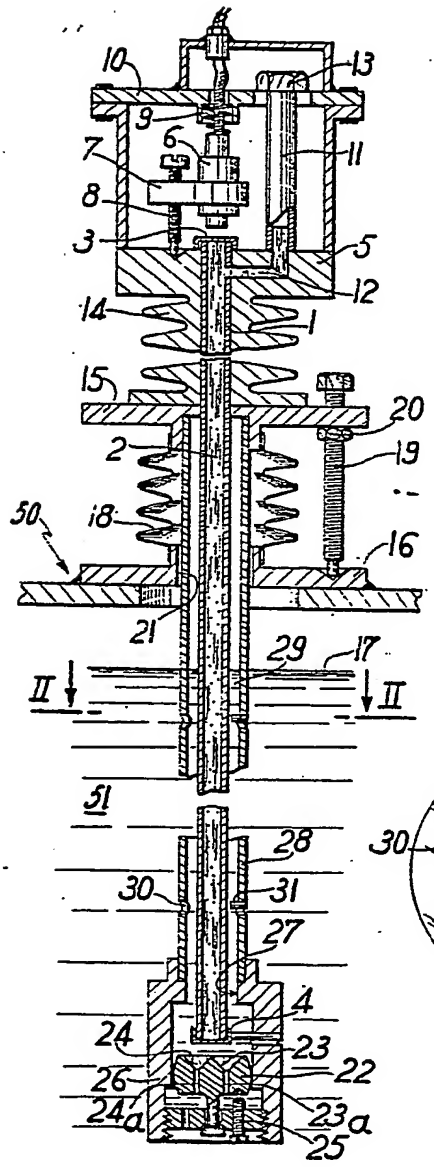

FIG. 1

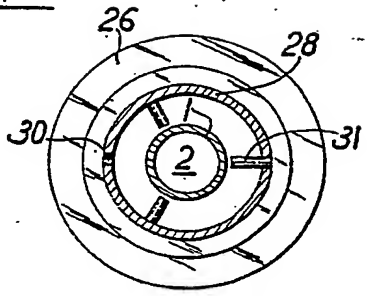

FIG. 2

1123939 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheets 1 & 2

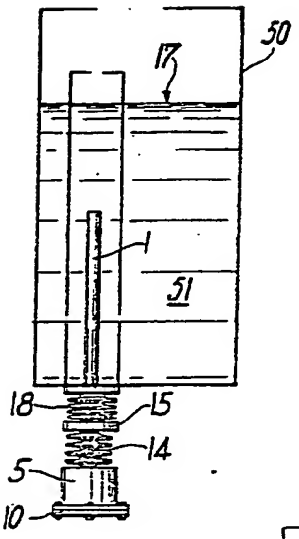

FIG. 3

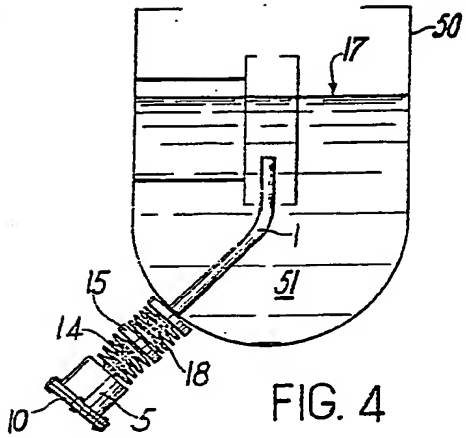

FIG. 4

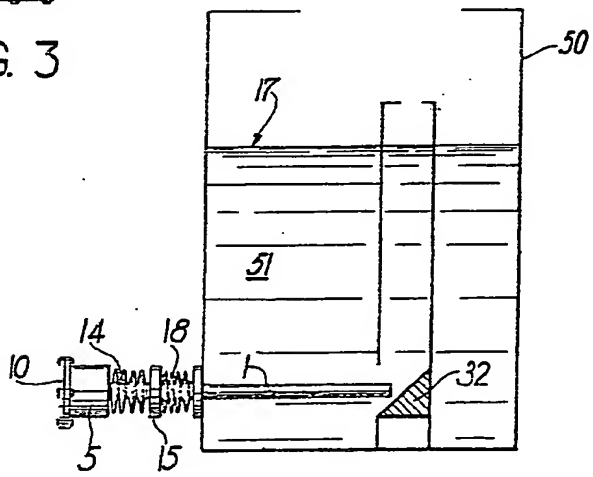

FIG. 5

1123939 COMPLETE SPECIFICATION
2 SHEETS This drawing is a reproduction of the Original on a reduced scale
Sheets 1 & 2

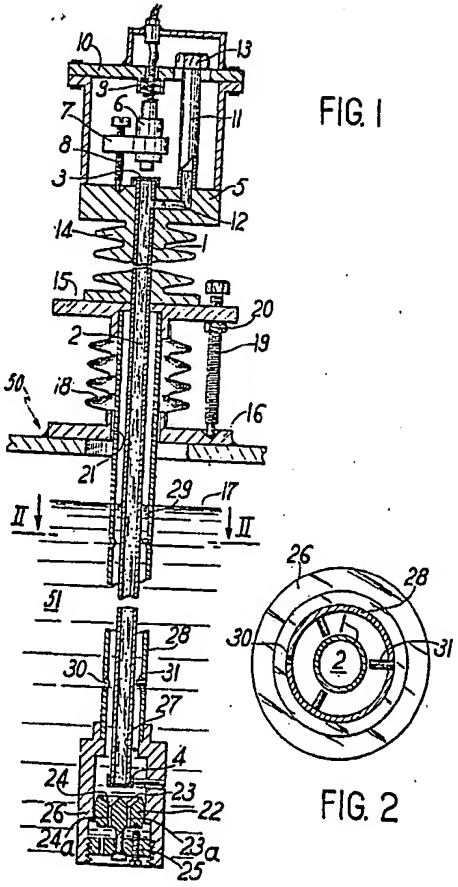

FIG. 1

FIG. 2

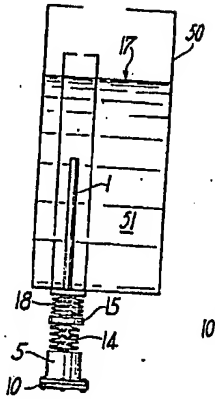

FIG. 3

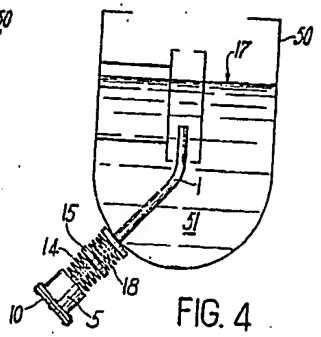

FIG. 4

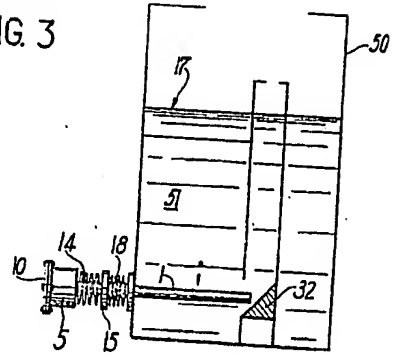

FIG. 5